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By G. H. Cunningham, Government Mycologist, Department of Agriculture, Wellington, N.Z.

(Plates xxiii-xxiv.)

[Read 28th July, 1926.]

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Species of this genus have been recorded from every continental area. They grow for the most part in pastures and sandy regions. In the genus are found the largest known "puff-balls", and in one species plants have been recorded as attaining a circumference of 135 cm.

Until the appearance of Morgan's paper (1890) species were placed under *Lycoperdon* or *Bovista*, according to whether a well-defined sterile base was present or absent. Morgan, however, clearly defined the genus as being separated from *Lycoperdon* by the method of dehiscence. In *Lycoperdon* the plant is perforated apically by a single aperture (stoma) through which the spores escape. In *Calvatia* this aperture is wanting, dehiscence being effected by the irregular breaking away of the upper portion of the peridium. Notwithstanding the fact that Morgan so defined *Calvatia* as to make separation from *Lycoperdon* a relatively simple matter, the genus has not yet become generally recognized in Britain and Europe, for it is usual to find species of *Calvatia* referred to *Lycoperdon* in the more recent systematic publications. When Morgan's classification is followed, confusion between the two genera is likely to arise with only two species, *Lycoperdon depressum* Bon. and *L. subpratense* Lloyd; for with these species an apical stoma appears as in other species of *Lycoperdon*, but this is followed by the breaking away of the greater part of the apical portion of the peridium, consequently weathered plants may quite readily be placed under *Calvatia*. As it is usual to obtain both mature and immature plants in the same collection, no difficulty in placing these species should arise, for the stoma is noticeable in plants which have just reached maturity.

Structure of the Mature Plant.

If plants are examined before dehiscence has commenced they will be seen to consist of a well-defined peridium, enclosing the gleba and (usually) a sterile base, which occupies the lower portion of the plant.

The peridium consists of two distinct tissues, an outer exoperidium, and an inner endoperidium. The exoperidium varies in its appearance according to the species. It is best seen in plants before the gleba has matured, appearing then as a tomentose layer, approximately 1 mm. thick. It is definitely pseudoparenchymatous, and exteriorly may be tomentose, floccose, or furfuraceous. It is often fissured, when it is said to be areolate.

The endoperidium is usually quite thin, smooth and brittle, but may be membranous or papyraceous. It is composed of thick-walled, intricately interwoven, septate hyphae. At maturity it flakes away from the apical portion of the

plant, but usually persists basally, especially on the exterior of the sterile base, when the latter is present. The sterile base varies considerably in its structure according to the species. In *Calvatia caelata* and *C. lilacina* it is separated from the gleba by a prominent diaphragm, composed of the same tissue as the endoperidium; in *C. gigantea* and *C. candida* this structure is absent, the gleba then merging almost imperceptibly with the sterile base.

In the two former species, the base is composed of a definite cellular tissue, the cells being distinct and large enough to be seen without magnification. In the two latter species, the tissue does not appear cellular, but is composed of intricately interwoven hyphae of the same nature as the capillitium threads; thus it is frequently a difficult matter to determine where the gleba ceases and the base commences. In mature plants the gleba becomes a deeper colour owing to maturation of the spores, consequently the point of separation of the gleba from the sterile base is then noticeable. This non-cellular tissue of the sterile base of the two latter species is here termed compact, to differentiate it from the cellular base of the other species.

The capillitium consists of very numerous, sparingly branched, septate, thick-walled hyphae. These arise from the inner walls of the endoperidium, and in those species in which a diaphragm is wanting, from the hyphae of the sterile base.

In two species, *C. lilacina* and *C. caelata*, the capillitium threads usually break up in the mature plant into numerous small lengths; consequently the whole gleba becomes pulverulent, and is soon dissipated. In the other species, this breaking up of the threads does not occur to the same extent, consequently the gleba persists often for one or more seasons; and indeed, one occasionally meets with the more or less intact glebal mass of *C. gigantea* from which the peridium and scanty sterile base has completely fallen away.

The spores are coloured, usually globose, and may be smooth (*C. caelata*), finely verruculose (*C. gigantea*, *C. candida*), or strongly verrucose (*C. lilacina*). Frequently portion of the sterigma remains attached to the spore, a condition here termed apiculate.

I am indebted to Dr. J. B. Cleland, Adelaide, for the loan of all specimens of this genus in his herbarium; and to Mr. H. Drake, Biological Laboratory, for photographs of the different species.

Calvatia Fries.

Summa Veget. Scand., 1849, 442, *p.p.*; emend.—Morgan, *Journ. Cin. Soc. Nat. Hist.*, 12, 1890, 165.

Peridium subglobose to pyriform, frequently with a well-developed rooting base; of two layers, an outer exoperidium which may be warted, spinose, furfuraceous, granular or smooth, and flakes away in irregular fragments; and an inner endoperidium which is thin, papyraceous or membranous, and flakes away irregularly from the apex, but persists towards the base; sterile base present, well developed or scanty.

Gleba coloured, of capillitium and spores; capillitium threads long, equal, sparingly branched, septate or continuous, attached to the inner walls of the endoperidium. Spores globose or shortly elliptical, continuous, coloured, rough or smooth.

Habitat.—Solitary or in small groups on the ground in pastures, sand-dunes or outskirts of the forest.

Distribution.—Britain; Europe; Asia; North and South America; India; Africa; Australia; New Zealand.

A small genus of about 8 species, containing most of the largest "puff-balls". Four species are present in Australasia, all being of wide distribution. The genus is separated from *Lycoperdon* solely by its means of dehiscence, which is effected by the irregular breaking away of the upper part of the peridium, and not by a definite apical stoma, as is present in *Lycoperdon*.

Key to the Species.

Diaphragm present.
- Spores smooth .. .. 1. *C. caelata.*
- Spores verrucose .. .. 2. *C. lilacina.*

Diaphragm absent.
- Plants large, exoperidium smooth, leathery .. .. 3. *C. gigantea.*
- Plants small, exoperidium furfuraceous .. .. 4. *C. candida.*

1. CALVATIA CAELATA (Bull.) Morgan. Plate xxiv, fig. 3.

Lycoperdon caelatum Bull., *Champ.*, 1, 1809, 156.—*L. Fontanesii* Dur. et Mont., *Fl. Alger.*, 1, 1849, 381.—*L. favosum* Bon., *Bot. Zeit.*, 15, 1857, 595.—*L. Sinclairii* Berk. in Herb.; Mass, *Jour. Roy. Micr. Soc.*, 1887, 716.—*Calvatia caelata* (Bull.) Morgan, *Journ. Cin. Soc. Nat. Hist.*, 12, 1890, 169.—*C. Fontanesii* (D. et M.) Lloyd, *Lyc. Aus.*, 1905, 36.—*C. favosum* (Bon.) Lloyd, *l.c.*—*C. Sinclairii* (Berk.) Lloyd, *l.c.*, p. 37.

Peridium 5-10 cm. diam., depressed-globose or subpyriform, tapering abruptly into a well-developed, crenulate, stem-like rooting base; exoperidium at first white, becoming pallid olivaceous, areolate, floccose, areolae more conspicuous basally; endoperidium brown, fragile, breaking away in irregular flakes from the apical portion. Sterile base well developed, persistent, separated from the gleba by a well-defined diaphragm, forming the lower third of the peridium, distinctly cellular throughout.

Gleba at first yellowish, becoming olivaceous; at first compact, becoming pulverulent; capillitium threads very long and flexuous, sparsely branched, septate, olivaceous. Spores globose, 4-5 μ diam., frequently apiculate; epispore olivaceous, perfectly smooth.

Habitat.—Solitary on the ground, frequent on sand-dunes near the sea coast.

Distribution.—Britain; Europe; North America; Algeria; Australia; New Zealand.

Queenstown, Otago, May, 1920, J. B. Cleland; **Otaki, Wellington, Nov., 1924, E. H. Atkinson.

I have not seen Australian specimens. The plant is characterized by the areolate peridium, smooth spores, prominent diaphragm and large, cellular base. Miss Wakefield has kindly examined the type of *Lycoperdon Sinclairii* at Kew. She states the specimen is an old one, sterile base only, and is quite smooth externally. She believes the spores and capillitium could be those of *C. caelata*. Consequently I have considered it a synonym of this species.

2. CALVATIA LILACINA (Berk. et Mont.) Lloyd. Plate xxiii, fig. 1.

Bovista lilacina Berk. et Mont., in Hook. *Jour. Bot.*, 4, 1845, 62.—*Lycoperdon novae-zelandiae* Lev., *Ann. Sci. Nat.*, ser. 3, vol. 5, 1846, 164.—*L. lilacinum* (B. et

** Specimens in my herbarium.

M.) Mass., *Jour. Roy. Micr. Soc.*, 1887, 706.—*Calvatia cyathiformis* (Bosc.) Morg., *Jour. Cin. Soc. Nat. Hist.*, 12, 1890, 168.—*C. lilacina* (Berk. et Mont.) Lloyd, *Lyc. Aus.*, 1905, 35.

Peridium up to 15 cm. diam., subglobose to subpyriform, tapering abruptly into a large, well developed, strongly crenulate rooting base; exoperidium smooth or more frequently floccose, cream to bay-brown, often areolate, thin, fragile, fugacious; endoperidium brown, thin, fragile, flaking away irregularly from the apical portion. Sterile base well developed, persistent, cellular at the periphery, hemi-compact within, separated from the gleba by a prominent diaphragm. Gleba some shade of purple, sometimes with a greyish tinge, at first compact, soon pulverulent; capillitium threads long, branched, septate, equal, pallid olivaceous. Spores globose, 5·5-7·5 μ diam., occasionally apiculate; epispore violaceous, verrucose.

Habitat.—Solitary on the ground, especially in sandy areas.

Distribution.—Southern Europe; North America; South Africa; Australia; New Zealand.

South Australia: *Locality unknown, F. R. Zeitz (2 collections); *Adelaide, Jan., 1924.

New Zealand: **Weraroa, Wellington, Oct., 1922, G.H.C.; **Mar., 1925, J. C. Neill; **Dunedin, Sept., 1922, Miss H. K. Dalrymple. **Otaki Beach, Wellington, Nov., 1924, E. H. Atkinson.

Characterized by the prominent sterile base, conspicuous diaphragm, and large, verrucose spores. The peridium and gleba are fragile, consequently the sterile base is often the only portion of the plant collected; nevertheless even this can be determined readily, owing to its structure. It is liable to confusion only with *C. caelata*, but may be separated by its peculiar, partly compact, partly cellular structure.

The peridium is usually stated to be smooth externally, but this is by no means a constant feature; on the contrary, in New Zealand, collections frequently show the exterior to be floccose and often areolate, sometimes so closely approaching *C. caelata* as to make identification difficult, but the verrucose spores serve to separate it.

Hollos (1904, p. 163) gives *Lycoperdon fragile* Vitt. as a synonym of *C. lilacina*. If his statement is correct, then the former name must replace the latter, for it has priority, being published in 1842.

3. Calvatia gigantea (Persoon), n. comb. Plate xxiii, fig. 2.

Lycoperdon giganteum Batsch ex Pers., *Syn. Meth. Fung.*, 1801, 140.—*Bovista gigantea* (Pers.) Nees, *Syst. Pilze*, 1817, 34.—*Lycoperdon Bovista* Fr., *Syst. Myc.*, 3, 1829, 29.—*Calvatia maxima* (Schaeff.) Morg., *Journ. Cin. Soc. Nat. Hist.*, 12, 1890, 166.—*C. gigantea* (Batsch) Lloyd, *Myc. Notes*, 1904, 166.—*C. primitiva* Lloyd, *Lyc. Aus.*, 1905, 36.

Peridium subglobose, up to 40 cm. diam., sessile, with a cord-like rooting base; exoperidium smooth, finely tomentose, closely resembling chamois leather, fragile, cream or yellowish, fugacious; endoperidium brown, thin, fragile, flaking away irregularly. Sterile base scanty and poorly developed, compact, frequently wanting, diaphragm absent.

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* An asterisk indicates that the collection in question is in the herbarium of Dr. J. B. Cleland, Adelaide; and where the collection is preceded by an asterisk, but no collector given, it signifies that the collection was made by Dr. Cleland himself.

Gleba yellowish, becoming olivaceous, hemi-compact; capillitium threads long, sparingly branched, septate, olivaceous. Spores globose, 4-5·5 μ diam., occasionally apiculate; epispore olivaceous, verruculose.

Habitat.—Solitary on the ground in pastures.

Distribution.—Britain; Europe; North America; Australia; New Zealand.

New Zealand: **New Plymouth, W. W. Smith, Dec., 1923; **Weraroa, Wellington, Mar., 1925, J. C. Neill; **Canterbury, Jan., 1926, J. C. Neill.

The large size, leathery peridium and absence of a well-developed sterile base characterize the species. The spores are usually stated to be smooth, but are distinctly verruculose under the oil immersion. This is the commonest species in New Zealand, and may regularly be found during the spring and autumn months in certain pastures in the lowland areas.

4. Calvatia candida (Rostk.) Hollos. Plate xxiv, figs. 4, 5.

Langermannia candida Rostk., in Sturm. *Deutsch. Fl.*, Bd. 3, Heft 18, 1837, 25.—*Lycoperdon candidum* (Rostk.) Bon., in Sacc. *Syll. Fung.*, 7, 1888, 483.—*Bovista tunicata* Bon., *Bot. Zeit.*, 15, 1857, 597.—*B. olivacea* Cke. et Mass., *Jour. Bot.*, 26, 1888, 133.—*Calvatia candida* (Rostk.) Hollos, *Term. Fuez.*, 25, 1902, 112.—*Calvatia olivacea* (C. et M.) Lloyd, *Lyc. Aus.*, 1905, 37.

Peridium up to 7 cm. diam., subglobose to pyriform, base frequently crenulate, tapering abruptly into a strongly developed, white, cord-like rooting base; exoperidium thin, furfuraceous, ochraceous, frequently areolate, fugacious; endoperidium thin, papyraceous, ochraceous or chestnut-brown, flaking away irregularly from the apex. Sterile base usually well developed, sometimes scanty, compact, yellowish, diaphragm absent.

Gleba pallid olivaceous, hemi-compact; capillitium threads sparingly branched, sparsely septate, equal, olivaceous. Spores globose, 4-5·5 μ diam., frequently apiculate; epispore olivaceous, finely and sparsely verruculose.

Habitat.—On the ground in small groups.

Distribution.—Europe; Australia.

South Australia: *Monarto South, Sept., 1920; *Adelaide, 1921; *Beaumont, Adelaide, May, 1922; *Kinchina, Apl., 1924, Miss Machlin; *Kinchina, July, 1923 (2 coll.); *F. R. Zeitz coll.

Victoria: Dimboola, F. M. Reader, Herb. Vic. Dept. Agr.

Judging from the specimens in Dr. Cleland's collection, this appears to be the most abundant species of the genus present in Australia. It is characterized by the usually well developed, compact sterile base, prominent rooting base, furfuraceous, thin exoperidium, verruculose spores and small size. Often in mature plants the sterile base appears somewhat cellular, but this condition is usually not apparent in mature plants.

I consider *Bovista olivacea* Cke. et Mass. but a synonym, for the original description is well covered by that given above. Lloyd (1905, p. 37) has examined the type specimen at Kew and states it is similar to *C. candida* but differs in the larger, thicker peridium, and more deeply coloured capillitium. Examination of individual plants in any abundant collection of *C. candida* will show that these differences are insufficient as specific characters, for the Australian forms range in size from 2 cm. to 7 cm. in diameter; the peridium is in young plants 1-2 mm. thick, and the colour of the capillitium varies according to whether the plants were collected while fresh or when weathered.

Var. RUBRO-FLAVA (Cragin), n. comb.

Calvatia rubro-flava (Cragin) Lloyd, *Myc. Notes*, 1902, 90.—*Lycoperdon rubro-flavum* Cragin, *Bull. Washburn Coll.*, 1, 1885, 30.—*Calvatia aurea* Lloyd, *Myc. Notes*, 1899, 11.

Closely resembling the preceding but separated by the reddish-ochre colour of the gleba.

Distribution.—North America; Australia.

New South Wales: *Neutral Bay, Mar., 1916.

I have compared Dr. Cleland's specimens with specimens kindly donated by Dr. Coker, University of North Carolina (No. 7163) and find them to be identical in all particulars save that of size, the Australian specimens being somewhat larger.

Var. FUSCA, n. var.

Closely resembling *C. candida* but differing in that the gleba is dark olivaceous, almost fuscous.

Distribution.—Australia.

South Australia: *Kinchina, July, 1923.

I believe it inadvisable to erect species upon the colour of the gleba alone, so have considered *C. rubro-flava* as being a variety of *C. candida*, for it agrees in all other particulars. The variety *fusca* is based on a single specimen which differs from *C. candida* only in the darker colour of the gleba.

If one were to consider glebal colour alone as being of specific value then many species must be erected in related genera; for example in *Disciseda hyalothrix* may occur specimens with olivaceous or purple gleba, yet these forms are not considered as being distinct species. Further, some plants of *C. rubro-flava* closely approach in colour certain plants of *C. candida*; and bleached specimens also appear so similar that separation becomes difficult and frequently impossible.

This is a matter of opinion, however, and to those desirous of basing species on glebal colour these two varieties would be considered as distinct species.

Literature Cited.

HOLLOS, L., 1904.—*Die Gasteromyceten Ungarns*. 278 pp. Leipzig.

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EXPLANATION OF PLATES XXIII-XXIV.

Plate xxiii.

1. *Calvatia lilacina*. Natural size. Sterile base only; note the conspicuous diaphragm.

2. *Calvatia gigantea*. × ½. Showing the rooting base and smooth, leathery exoperidium.

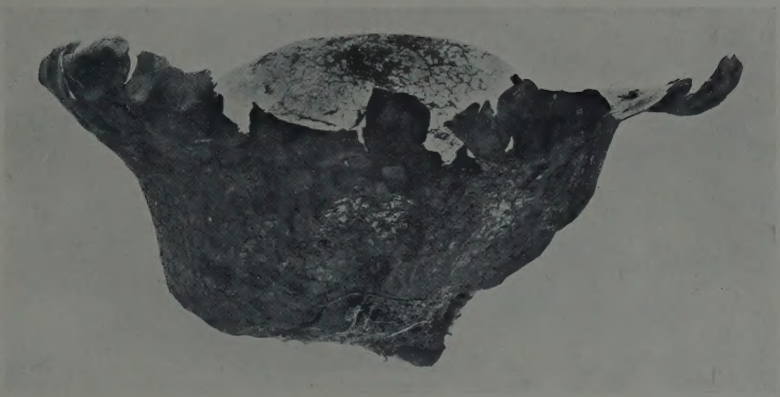
Plate xxiv.

3. *Calvatia caelata*. × 0·9. The areolate, floccose exoperidium is here well shown.

4. *Calvatia candida*. × 0·9. The plant on the right is inverted to show the rooting base. Note the furfuraceous exoperidium, strongly fissured in these plants.

5. *Calvatia candida*. × 1·8. Section showing the sterile base. In this photograph the base appears distinctly cellular owing to the fact that the plant is not yet mature.

All photographs by H. Drake.



1. *Calvatia lilacina.*

2. *Calvatia gigantea.*

3. *Calvatia caelata.* 4, 5. *C. candida.*